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Multi-Model Ensemble Approaches to Data Assimilation
Using the 4D-Local Ensemble Transform Kalman Filter

Kayo Ide
University of Maryland
phone: (301) 405-0591   fax: (301) 314-9482   email: ide@umd.edu

Award Number: N000141010557
http**://**www.atmos.umd.edu/~ide

LONG-TERM GOALS

Uncertainties in the numerical prediction using a computational model of a physical system arise from two primary sources: i) errors within the model itself; and ii) imperfect knowledge of (a) the initial conditions to start the model and (b) boundary conditions and the forcing that is required to run the model. One way to examine these uncertainties is the multi-model approach, i.e., to compare results from multiple models. However, the multi-model approach cannot completely address either (i) or (ii) due to lack of knowledge of the real state. Another way is to compare the results with the "observations" that sample the real state. However, the observations introduce another source of uncertainties, i.e., iii) imperfect knowledge and/or improper assumptions within the observations including sampling error.

The ultimate objective of this project is to develop a framework for two purposes: one is the maximum reduction of the reducible uncertainties and the other is the diagnosis of the irreducible uncertainties in the numerical prediction. We will use a data-assimilation approach, which is ideal for this problem. Data assimilation is a method that was developed to primarily address the issues related to (ii-a) above by merging the observations into the numerical prediction. It attempts to optimally combine the "background"(or "forecast") information obtained by a short-term forecast using a numerical model with the observations taken within the forecast time window. The resulting state is the so-called "analysis", whose uncertainties are expected to be smaller than both the background and the observations. Some of these uncertainties are reducible by improving the data assimilation method. Other uncertainties are irreducible.

OBJECTIVES

To pursue our objectives, we will, for the first time, integrate data assimilation into the multi-model approach. The Local Ensemble Transform Kalman Filter (LETKF) is our choice of the data assimilation method. Because it uses an ensemble to estimate the state uncertainties, it offers a perfect vehicle for the multi-model approach. In addition, a number of advantageous algorithms have been developed for the quantification and the reduction of uncertainties of all three types (i) - (iii), including both model-bias correction and observation-bias correction. Bias corrections, in a sense, transform part of the irreducible uncertainties (by other methods) into the reducible uncertainties. By integrating it into the multi-model approach, the LETKF will gain a powerful additional advantage: the combination of the ensemble weights and the calibration of the model will lead to improved performance over a

single model LETKF. The resulting uncertainties are irreducible by the multi-model LETKF. We will extend the sensitivity diagnostics to examine the impact the observations and the background (forecast) in the uncertainty reduction using the multi-model LETKF.

APPROACH

To develop our framework, we will take hierarchical approach and use Observing System Simulation Experiments (OSSEs). We will start from a simple ocean-atmosphere coupled model in order to develop algorithms appropriate for this new approach. The optimal framework will be then tested with the sophisticated Regional Ocean Model System (ROMS).

WORK PURSUED

Because of the funding delay and difficulty in hiring a postdoctral fellow, we are yet to really start the project. However, in the conjunction with another ONR grant (please see below), we have been building up a foundation for this project. This includes: 1) implementation of the nested Regional Ocean Modeling System (ROMS) for the Chesapeake Bay's estuary system; 2) advancement of data assimilation schemes based on the ensemble Kalman filter, with foucs on: localization effect; model resolution effect; multi-scale approach to data assimilation. In addition effectiveness of particle filters were examined fo a system subject to nongausian error in dynamics.

RELATED PROJECTS

N000140910418. Uncovering the Geometry of Ocean Flows and the Assimilation of Lagrangian Type Data